CONVERSION TABLES FOR VARIOUS VISCOSIMETERS

BY

H. M. GOODMAN

H. LUTTGE

ARMOUR INSTITUTE OF TECHNOLOGY

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Conversion tables for
various viscosimeters using

CONVERSION TABLES FOR VARIOUS VISCOSIMETERS

USING THE SAYBOLT UNIVERSAL VISCOSIMETER
AS THE STANDARD

A THESIS

PRESENTED BY

HARRY M. GOODMAN AND HAROLD LUTTGE

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BACHELOR OF SCIENCE
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Professor of Mechanical Engineering

Dean of Engineering Studies

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OBJECT.

The cry of the present age of the engineer is for standardization. Perhaps the one field of activities which has been neglected is the testing of lubricants. In the past, various types of viscosimeters have been used for testing the viscosity of oils, which has created a great deal of confusion. At present time the tendancy of the larger oil manufactors is to use a standard type of viscosimeter. It is therefore the aim of the writers to study the various viscosimeters at their command and to construct tables and curves whereby the viscosity of any meter can be readily transfered into the corrosponding value on the Saybolt Universal Viscosimeter.

We wish to express our thanks to Prof. James Clinton Peebles for his cooperation and suggestions.

Harry M. Goodman.

Harold Luttge.

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INTRODUCTION.

The object of mechanism is the utilization of energy for the purpose of doing ueeful work. Owing to the imperfections of our methods, a large part of the applied energy is wasted in various ways; namely in overcoming resistance to relative motion offered by the opposing surfaces, and it is in order to reduce this friction to a minimum that lubrication is applied.

The viscosity test is of great value in determining the lubrication properties of oils. Before the introduction of mineral oils as lubricants, the theory of viscosity was relatively ignored by the engineers as the oils were limited in numbers and the viscosity did not vary greatly. Therefore a specification for an oil of a certain fluidity was unknown. But since the introduction of mineral oils which can be prepared of any viscosity, the measurement of this property has become important.

Bt viscosity tests, we can alone determine the lubrication properties to such an extent that a poor oil would not be accepted nor a good oil

rejected. Before entering upon the discussion of the various viscosimeters and the method of operation, the nature of viscosity and the theory of the viscosimeter shall be considered.

The Nature of Viscosity.- When currents are produced in fluids, forces are observed which retard the relative motion of the parts. These forces of friction are said to be due to the viscosity or as it is sometimes expressed, its "body". The greater the viscosity, or internal friction, the more viscous the fluid. All liquids exhibit viscosity, although in varying degrees. If a vessal be tilted and then quickly brought back to place so as to agitate the water contained therein, it will be found that the degree of oscillations diminishes, and that in a very short time the movement dies away. The liquid will again come to rest in a horizontal position. If this experiment be made with a very viscous oil, the liquid will not show a very marked degree of oscillation. Very often it will flow steadily until its

free surface is again horizontal; It is the internal friction or viscosity of the liquid which arrest the motion.

Theory of the Viscosimeter.- The instruments employed for the determination of viscosity are constructed upon two different principes: one depending upon the time required for a certain quantity of oil to flow through a standard orifice; the other, upon the time it takes a disk to rotate through a certain arc. As the former type of instruments were used in this work, it is important that the theory of the orificial instrument be understood.

As the viscosity is measured by the time of efflux through a capillary tube, it is important that we study the theory of such a meter. The most concordant values have been obtained by measuring the rate of flow through a capillary tube in which the rate of shear is the greatest at the bounding surfaces.

COMPARISON OF VISCOSIMETERS

Figure 1 shows diagrammatically the conditions of flow in a capillary tube at a point some distance from the end at which the liquid enters. A state of equilibrium must be established for the effects of inertia manifest themselves at the inlet end.

In a portion of a tube of length a, the whole pressure on the cross-section CC_1 tends to shear the liquid at the bounding surface and the area over which this pressure acts is equal to $2\pi r_o a$. Therefore the total pressure over the section in question is $p\pi r^2_o$, where the area of the cross-section of the tube is equal to πr^2_o. The rate of shear at the boundary is given as;

$$\frac{p\pi r^2_o}{Nx2x\pi xr^2_oxa} \qquad \text{which is equal to}$$

$$\frac{pr}{2Na} \qquad (1)$$

where N is a constant which varies with the temperature of any liquid and is known as the " Coefficient of Viscosity" of that liquid. It follows from the equation (1) that the rate of shear is directly proportional to the distance from the senter line of the tube, and the curve which indicates the rate of distortion is a parabola. The volume passed in a unit

of time is the volume of the paraboloid of revolution, having a base of radius r_o and a height equal to B_1E_1 which is equal to $\frac{1}{2}B_1A_1$ (figure 2).

From (1) we have

$$\frac{B_1A_1}{B_1C_1} = \frac{pr}{2Na} \tag{2}$$

Therefore $B_1A_1 = \frac{pr^2_o}{2Na}$

and $$B_1E_1 = \frac{1}{2}B_1A_1 = \frac{pr^2_o}{2x2Na} = \frac{pr^2_o}{4Na} \tag{3}$$

The volume of a paraboloid of revolution equals one half the area of the base times the perpendicular height. Substituting the above values in equation (3) the volume V passes in any time is equaled to

$$V = \frac{\pi}{8} \cdot \frac{pr^2_o t}{Na} \tag{4}$$

We may find an expression for the viscosity of the liquid from the above equation by substituting for p its equivalent in terms of the head and density of the liquid and the force of gravity, i.e.,

$$N = \frac{\pi gyhtr^2_o}{8Va} \tag{5}$$

where N equals the coifficient of viscosity.

g " " force of gravity.

y " " density of the liquid.

h " " head.

r " " radius of the tube.

t " " time of efflux in seconds.

a " " length of the tube.

V " " volume of liquid.

Equation (5) is known as Poiseulle's Formula. This formula will give the viscosity in the absolute measure. Mr.R.C.McIlhinney suggests that in order to do away with the various values of viscosity, that we apply Poiseulle's Formula; that instead of calling N the coefficient of viscosity, that it be known as a Poise, in honor of Poiseulle. Although we do not use the absolut measure of viscosity in the commercial world, yet the measure of viscosity if determined by the time of efflux through a capillary tube.

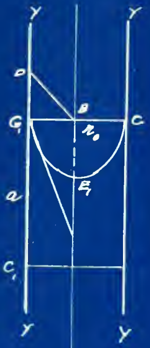


FIG 2.

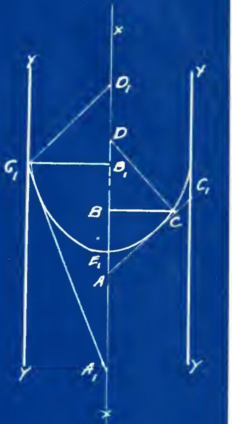


FIG. I

THE THEORY OF LUBRICATION.

Objects of Lubrication.- The engineer has seldom to deal with unlubricated rubbing surfaces in the design of machinery. His object is to transmit energy and its its utilization to some particular place with as little loss as possible. In effecting this, the moving surfaces are pressed together with a considerable force and caused to slide over each other at high speeds. If these surfaces are not kept apart by the interposition of a lubricant, the frictional losses will be very great, causing a wear and tear of the surfaces. If it were not for the properties of certain liquids and soft solids that possess the quality of keeping the relatively moving parts separated and, thereby reducing the frictional resistances between them, it would be impossible to carry on many of the important manufacturing processes which require high speeds. A great deal of power output of prime movers is wasted through friction. It is therefore important to procure the right kind of lubricant.

Theory of Lubrication.- Until recently, the

engineer had to be guided by previous experience in the design of bearing surfaces. This was due to the fact that the theory of lubrication or the action of viscous substances in diminishing friction had received little attention. There had been some data gathered, but the results were not uniform, nor do they agree with the general experiences of engineers concerning the frictional resistances of machinery.

The theory of lubrication is bases upon the supposition that a lubricant acts in virtues of its viscosity, the physical properties which cause the fluid to interpose itself between the moving surfaces and keep them apart.

Influence of Viscosity.- The thickness of the film of lubricant affects the degree of frictional resistances. It has been found that the friction of a cylindrical journal should be proportional to the viscosity of the lubricant. The reason for believing that the resistance does not increase at a rate proportional to the speed is that the rapid distor-

tion which the oil undergoes heats it and lowers its viscosity. Very often the reduction in the frictional resistances which results from the lowering of the viscosity by heating is by no means advantageous. This accounts in a great measure for the failure of bearings to carry heavy loads at high speed. If the proper oil is not used the increase of temperature causes the oil to become very thin and it will cease to lubricate properly. This is particularly so with the mineral oils.

VISCOSITY AND VISCOSIMETERS.

The Method of measuring the viscosity of the oil will be considered at this time. Various means have been proposed and devised, based upon such observation as the rate of ascent of air bubbles in a liquid; the torsional vibration of a disc in its own plane when suspended by a wire and immersed in the liquid; the speed of rotation of paddle wheels, discs, etc., immersed in the liquid and kept in motion. The most accurat and the usual method of proceedure is that of Poiseulli, in which the rate of flow of a liquid is measured by the time it takes a known quantity of liquid to flow through a capillary tube under a certain temperature and head. For commercial purposes, the comparative viscosities of oils are ascertained by measuring and comparing the time of efflux of that oil through a small orifice.

A very rough idea of the relative viscosity of an oil with another may be formed by shaking it in a bottle and observing the rate at which air-bubbles rise in the oil; the more sluggish the move-

ment of equal sized bubbles, the greater the viscosity of the oil. A second method less crude than that above and more accurate is to fill a 10 c.c. pipette with the oil and note the time in seconds occupied by the oil in flowing from the higher mark to the lower. By making a similar experiment with another oil at the same temperature, a comparison between the two samples can be made. But for accurate work a properly constructed viscosimeter must be employed.

DESCRIPTION OF VISCOSIMETERS.

Introduction.- In practice, the viscosimeter is held is a heavy metal frame suspended vertically from a pivot. This is contained in a water or an oil jacket, the temperature of which is kept constant during a run, but which can be varied for any desired temperature. Viscosimeters are divided into three general classes: first, where the rate of flow is measured by the time of efflux through a capillary tube, of which the Saybolt and the Tagliabue viscosimeters are a type; second where the liquid flows

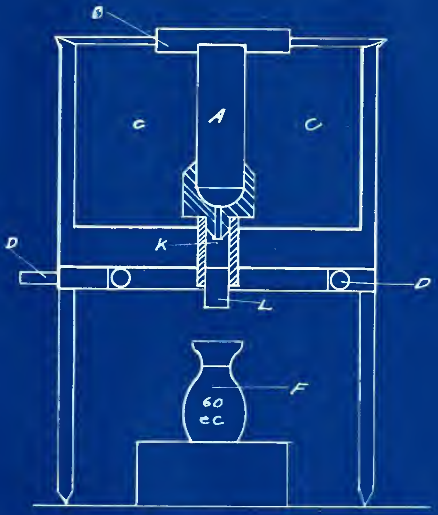
through an orifice, which type the Carpenter constant head viscosimeter is the representative; and the third the torsional viscosimeter which was devised by Mr. O.S.Doolittle. The measurement of viscosity is expressed in the numbers of seconds it takes a disc to complete an arc.

We shall study the four viscosimeters that were used in order of their importance and describe briefly the methods employed in finding the viscosity. The four experimented with were: (1) Saybolt's Universal; (2) Tagliabue's Viscosimeter; (3) the Armour Institute of Technology Viscosimeter, which is a modification of the Tagliabue; and the (4) the Carpenter constant head.

Saybolt Universal Viscosimeter.- The Saybolt Universal is the best know apparatus in the United States and is considered the standard. The instrument, figure 3, is constructed of metal throughout. The efflux tube consists of a wide cylindrical portion a, surrounded by a fixed pan which is the overflow basin. The oil

in this basin may be removed by a pipette. The tube A ends at the lower end in a metal jet K which is contained the capillary tube. C C is a tank filled with a heavy jacket oil. The oil may be heated by one of three methods; by a gas burner installed at D D, by steam passing through suitable pipes, or by an electric heater immersed in the oil.

The outer bath, tank C C, is filled with a heavy cylinder oil and heated to the desired temperature. The tube A is filled to overflowing with the oil to be tested. The surplus oil in the basin is removed, leaving the oil in the tube at the required head. This ensures a positive starting head. When the liquid has reached the temperature to which the viscosity is to be taken, the cork L is removed at the same time that the operator starts a watch. The instant the oil reaches the 60 c.c. mark on the flask the watch is stopped, and the time recorded. The total number of second for this volume of oil to flow through the aperture is termed the viscosity of the oil, in terms of the Saybolt Viscosimeter.



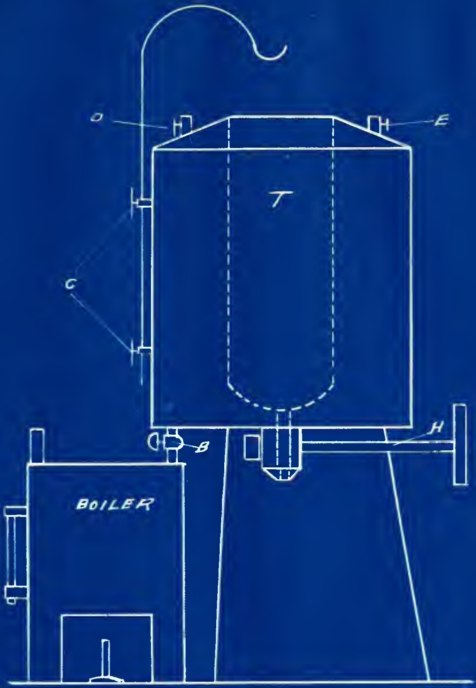
SAYBOLT UNIVERSAL
VISCOSIMETER

FIG. 3

COMPARISON OF VISCOSIMETERS

The Tagliabue Viscosimeter.- The viscosity in terms of the Tagliabue is the number of seconds multiplied by two that it takes 50 c.c. of oil to flow through an open faucet. The Tagliabue instrument is supplied with two nozzles, one to be used for finding the viscosity at 212 degrees, the other for 70 degrees.

To find the viscosity at 212 degrees.- The boiler A figure 4, is filled with water. The stop cock B is opened making connections between the boiler and the upper vessel which surrounds the tube T, containing the oil to be tested. A wire holder is placed in the set nut C, and a thermometer suspended so that its bulb is within one quarter of an inch from the bottom of the oil. The oil should be strained before placing it in the tube T. The stop cocks D and E are closed. The extension F is screwed into the coupling G, letting the end of the hose immersed in a vessel of water. A fire is started under the boiler. When the heat in the oil has reached 212 or the desired temperature, the



TAGLIABUE VISCOSIMETER

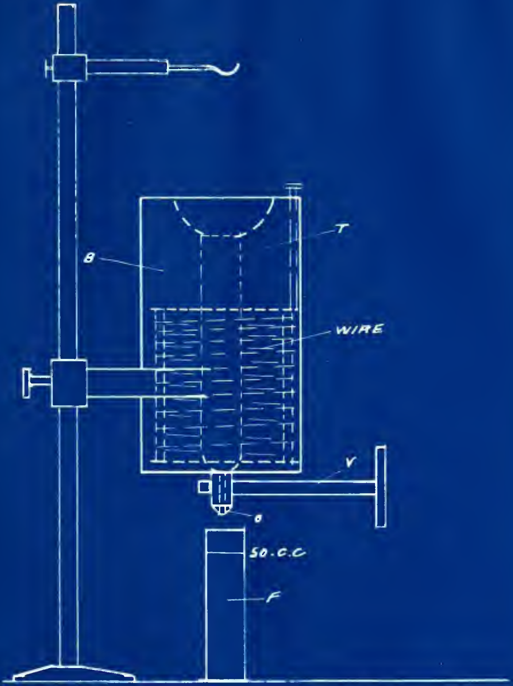
FIG 4

faucet H is opened, simultaneously with the startin of a watch. When the oil has reached the 50.cc mark on the flask, the watch is stopped and the time recorded. Multiplying the number of seconds recorded by two gives the viscosity of the liquid.

To test the viscosity of oils at 70 degrees.- The stop cock B and E are closed. The upper vessel is filled with water having the desired temperature or nearly so. By adding hot or cold water, the temperature is regulated. As soon as the oil in the tube T reaches the predetermined temperature, the run is made.

Armour Institut Viscosimeter.- The dimensions of this instrument was patterned after the Tagliabue. It consists of a tube T enclosed in a metal bath B. The viscosimeter is mounted on a frame as shown in the cut on page 23, figure 5. The orifice is shown at O. The jacket oil is heated by means of an electric coil which is mounted in the tank B.

The oil to be tested is placed in the tube T.



ARMOUR INSTITUTE TECHNOLOGY
VISCOSIMETER

FIG. 5

The jacket oil is heated to the desired temperature. When the oil in the tube T has reached that temperature, the valve V is opened which places the orifice parallel to the vertical axis. The liquid flows into a 50 c.c. flask F. The viscosity of an oil in terms of this viscosimeter is determined by the time it require 50 c.c. of oil to pass through the orifice, multiplied by two.

Carpenter Constant Head Viscosimeter.- A cup A figure 6, with a capacity of about 125 c.c., is surrounded with a jacket D, in which may be placed either water or oil depending upon what temperature is to be maintained. C is a thermometer cup to the bottom of which is secured a small cap containing the orifice F. N is a channel connecting the chamber containing A with C; B is a small tube which admits air to the interior of the cup and thus maintains atmospheric pressure on the oil. This secures a constant level of the oil surface in the space C. H is a valve to retain the oil in A while placing it into D. The mechanism G is a device for opening or clos-

ing the orifice. It is held in place by a spring catch L. The oil in the jacket D is heated by means of a gas burner placed beneath the projecting prongs P.

The cup A is withdrawn and filled in an inverted position with the oil, reinverted and placed in position in the instrument. This final step causes the valve H to raise allowing the oil to flow out until the chamber N and C are filled a little above the lower opening of the tube B. A beaker whose capacity should be 100 c.c. is placed under F; L is released and G is dropped, permitting the oil to flow through F into the beaker. When the oil in the space C falls below the bottom the tube B, the air is permitted to flow into the cup. The oil continues to flow out until the height has reached its level and the operation is repeated. This action continues throughout the entire run intermittenly but so rapidly that practically constant head is maintained at F. The viscosity of an oil in terms of efflux is the time it require 100 c.c. to flow through the orifice.

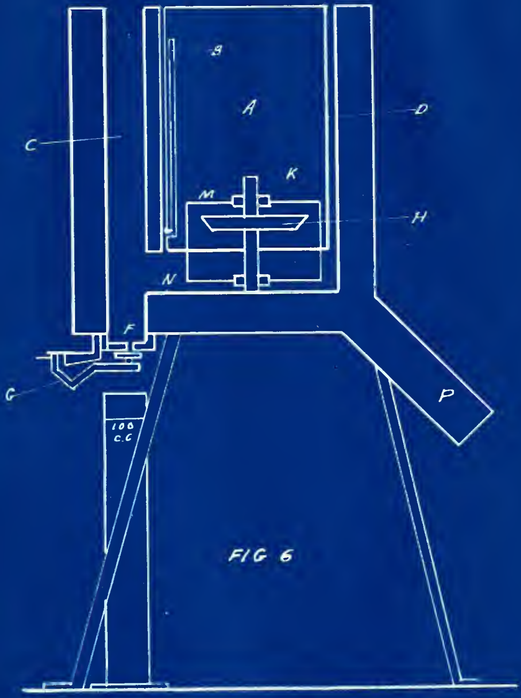


FIG 6

CARPENTER CONSTANT HEAD VISCOSIMETER

RESULTS OF TESTS.

Viscosity Values.- Although viscosity is definite property, which can be found experimentally and expressed in absolute measure, it has been the custom to use some oil as a standard, and to compare the fluidity of oils with it. This is objectional as the standard will vary in itself. Notwithstanding the effort which have been made for a uniformity the measurement and expressions of viscosity values are different. This is due to the fact that there are many viscosimeters on the market differing from each other in general dimensions and in pattern. Even though the results mean something and are correct, they mean nothing except to the possessor. The adoption of any particular instrument is not to be expected.

It is for these reasons we have determined data showing the comparison of the various viscosimeters available. The results from the various viscosimeters permit the construction of a set of curves whereby the reading of one instrument can be converted into those of another. The results are shown in the tables and curves. The horizontal distance refer to the

on the Saybolt Universal Viscosimeter. The vertical distance which is laid off in the same units represents the viscosity on any of the other apprartus. A comparison cannot only be made with the Saybolt but with any other. As for example; at 100 degrees the viscosity on the Tagliabue which is 75, is equal to 80 on the Saybolt, or to 58 on the Armour. A viscosity of 95 on the armour at 212 degrees is equal to 69 on the Tagliabue. Curves were constructed for temperatures of 100, 150, 212, 250, and 300 degrees, where the construction of the meter would permit. It was unable to procur results on the Tagliabue and Carpenter over 212 degrees. Twenty-four samples of oils varyiny in viscosity were used in procurring the desired results.

A set of tables shown on pages 30 to 33 were constructed and a value of n, the conversion factor for the ratio of the Saybolt to the other apparatus.

COMPARISON OF VISCOSIMETER.

Interpretation of Curves.- The tables showing the value of n were taken from the curves. The curves were drawn through the average position of the points. The curves show that there is a definit slope, or n, for any one viscosimeter. By finding the average value of n, shown in the tables, for each apparatus at each temperature, we find that the above statement is true. The value of n for the Saybolt vs the Armour is 1.08, i.e., by multiplying the viscosity as shown by the Armour Viscosimeter, we arrive at the viscosity on the Saybolt. The value of n for the Saybolt and Tagliabue is 1.06, while n for the Saybolt and Carpenter is 2.25. This is based on the assumption that the ratio is a straight line passing through the origin.

TABLE 1.

Value of Conversion Factor n.

at 100°

Saybolt	Tagliabue	n	Armour	n	Carpenter	n
30	27	1.11	38	0.79	26	1.15
40	37	1.06	42	0.95	28	1.43
50	47	1.07	46	1.09	30	1.66
60	56	1.07	49.5	1.21	32	1.88
70	66	1.06	54	1.30	34	2.06
80	75	1.07	58	1.38	36	2.22
90	85	1.06	62	1.45	38	2.40
100	85	1.05	65.5	1.52	40	2.54
110	104	1.06	70	1.57	41.5	2.65
120	114	1.05	73.5	1.63	43.5	2.76
130	123	1.05	77.5	1.67	45	2.89
140	132	1.06	82	1.71	47.5	2.95
150	142	1.06	86	1.75	49	3.06
160	151	1.06	90	1.78	51	3.14
170	161	1.06	94	1.81	52	3.20

TABLE 2.

Value of Conversion Factor n

at 150°.

Saybolt	Armour	n	Carpenter	n
30	31	0.97	28.5	1.05
40	37	1.08	29.0	1.37
50	42.5	1.18	29.5	1.70
60	48.5	1.24	30.0	2.00
70	54.5	1.28	31.0	2.26
80	60.5	1.32	31.25	2.54
90	66.5	1.35	32.	2.82
100	72.5	1.38	32.5	3.07
110	78.5	1.40	33.	3.24
120	84.5	1.42	33.5	3.58
130	90.5	1.44	34.	3.82
140	96.5	1.45	34.75	4.05
150	102.5	1.46	35.25	4.23
160	109.	1.47	36.	4.45
170	115	1.48	36.5	4.66

TABLE 3.

Value of Conversion Factor n

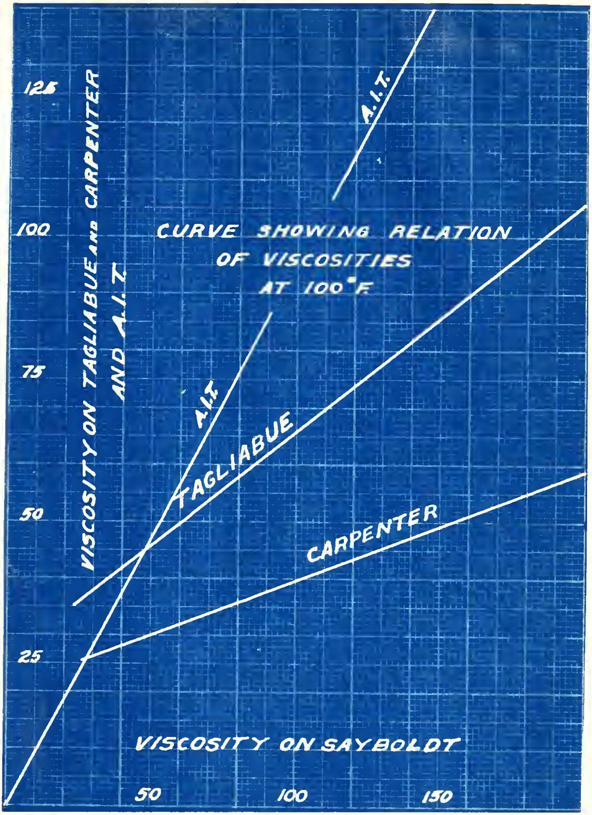
at 212°

Saybolt	Tagliabue	n	Armour	n
30	30	1.00	62	0.484
40	37	1.08	69	0.58
50	45	1.11	75	0.66
60	53	1.13	82	0.73
70	61	1.15	89	0.786
80	69	1.16	95	0.84
90	77	1.17	102.	0.925
100	85	1.18	108	0.965
110	92	1.20	114	0.965
120	100	1.20	120	1.00
130	108	1.20	127	1.03
140	116	1.20	133	1.05
150	124	1.21	140	1.07
160	132	1.21	146	1.10
170	140	1.22	154	1.11

Table 4.

Value of Conversion Factor n

250°			300°		
Saybolt	Armour	n	Saybolt	Armour	n
30	29	1.035	0	0	0
40	35	1.140	10	9.25	1.08
50	41	1.122	20	18.5	1.08
60	47	1.290	30	27.75	1.08
70	53	1.320	40	37.0	1.08
80	59	1.360	50	46.25	1.08
90	65	1.380	60	55.50	1.08
100	71	1.410	70	64.50	1.08
110	77	1.430	80	74.00	1.08
120	83	1.440	90	83.50	1.08
130	89	1.460	100	92.50	1.08
140	95	1.470	110	101.75	1.08
150	101	1.480	120	111.00	1.08
160	107	1.500	130	120.25	1.08
170	113	1.550	140	129.75	1.08


CURVE SHOWING RELATION
OF VISCOSITIES
AT 100°F
VISCOSITY ON TAGLIABUE AND CARPENTER
AND A.I.T.
VISCOSITY ON SAYBOLDT
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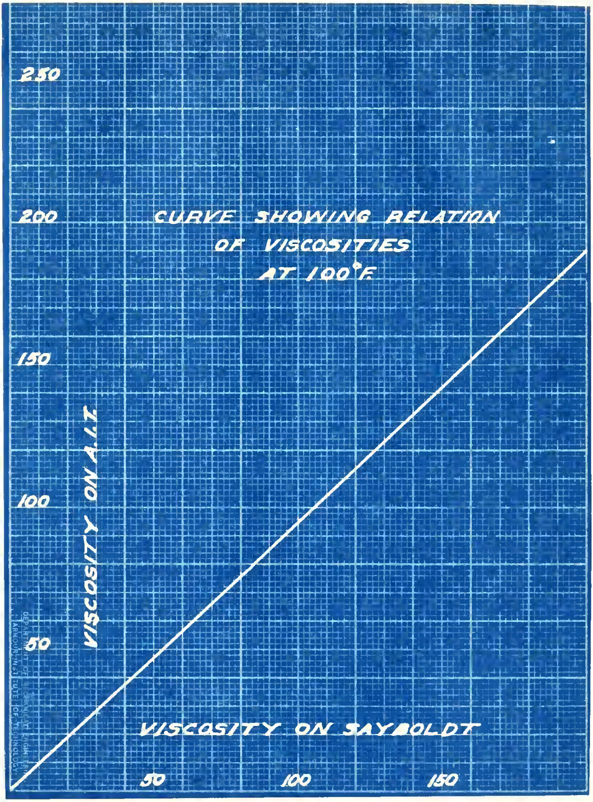
TAGLIABUE
CARPENTER


CURVE SHOWING RELATION
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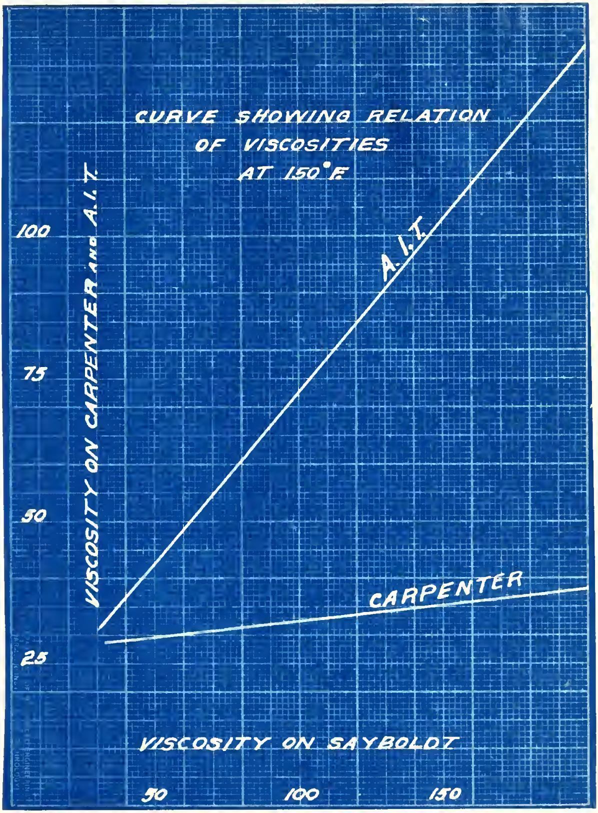
CURVE SHOWING RELATION
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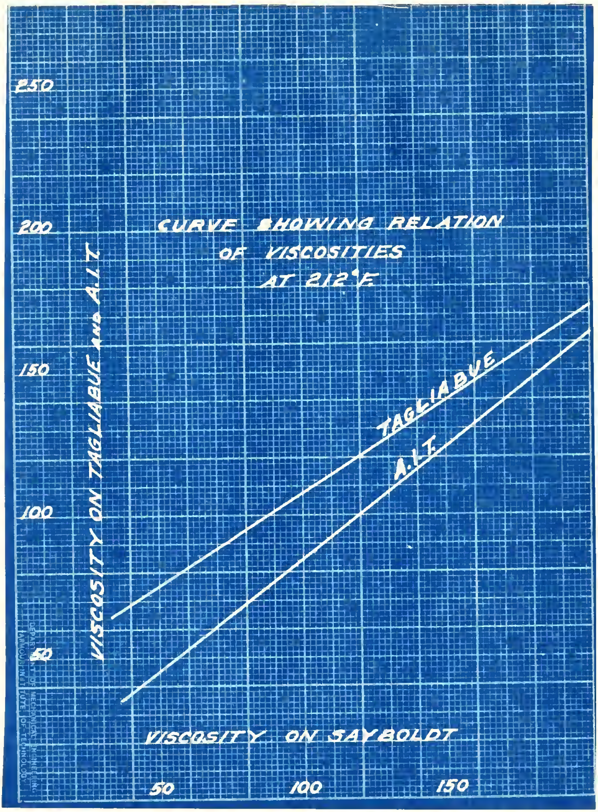
CURVE SHOWING RELATION
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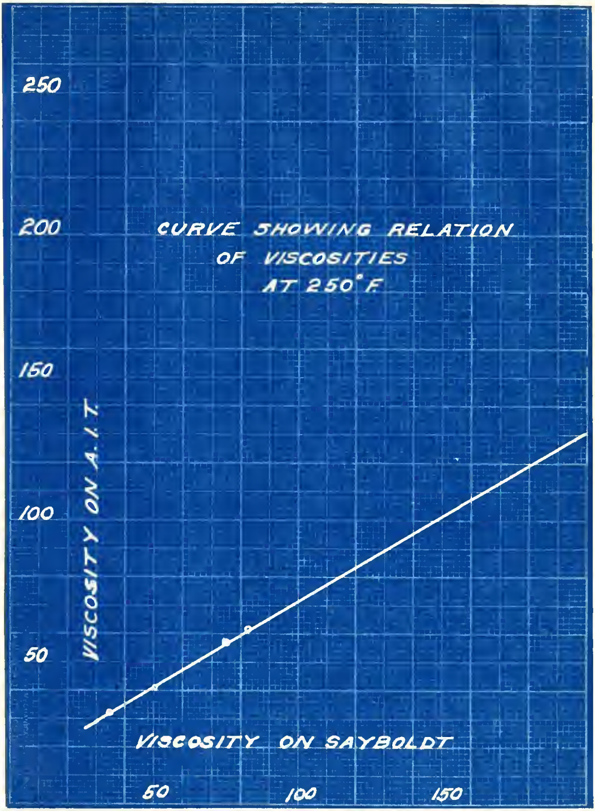
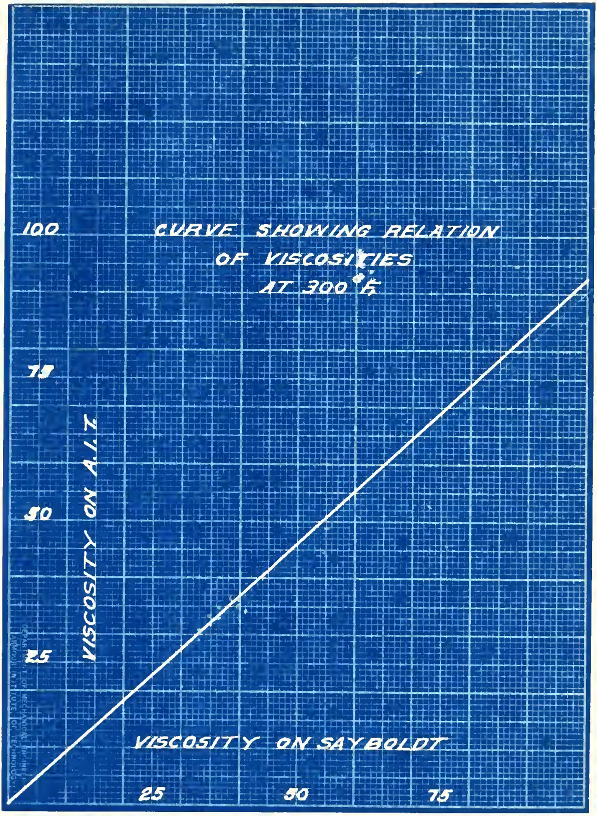

CURVE SHOWING RELATION
OF VISCOSITIES
AT 250° F
VISCOSITY ON A. I. T.
VISCOSITY ON SAYBOLDT
250
200
150
100
50
50
100
150


CURVE SHOWING RELATION
OF VISCOSITIES
AT 300° F.
VISCOSITY ON A.I.T.
VISCOSITY ON SAYBOLDT
100
75
50
25
25
50
75
DEPARTMENT OF MECHANICAL ENGINEERING
ARMOUR INSTITUTE OF TECHNOLOGY

DATA.

Average Results.

	Saybolt	Tagliabue	Armour	Carpenter.
100°	94.0	-	-	38.6
	141.0	117.72	-	49.0
	140.5	82.0	-	48.0
	135.6	81.6	-	46.0
	63.0	50.9	66.8	33.0
	73.0	-	74.4	33.0
	155.0	84.9	153.5	46.0
	123.5	74.8	101.0	
	77.4	117.5		
150°	66.5	-	-	30.4
	87.3		67.6	33.0
	84.3		64.6	34.0
	68.5		-	33.0
	45.2		41.7	27.0
	48.0		40.5	30.0
	73.0		58.4	33.0
	61.2		58.6	31.5
	77.4		57.6	31.2
	76.0		58.5	32.0
	101.5		61.6	34.5
	102.0		64.0	34.5
	79.7		59.6	32.7
	48.7		60.0	33.0
	74.0			
	95.0		71.6	34.8
	98.2		69.2	36.5
212°	42.0			
	46.2	73.72	42.8	29.6
	46.0		40.4	28.6
	45.0	71.8		
	37.0	65.6	33.6	26.2
	38.7		35.0	
	45.5	71.0	40.1	29.0
	44.4		39.8	
	47.4	72.2	42.0	28.8
	46.7		41.0	
	57.7	90.0	51.2	
	53.3		52.4	
	46.5	71.6	42.0	
	42.0		40.0	
	45.5	77.5	45.5	
	51.2		44.0	
	55.5	79.4	47.6	
	64.5	84.8	51.6	
	120.6	120.0		
	105.6	112.4	87.2	

DATA.

Average Results.

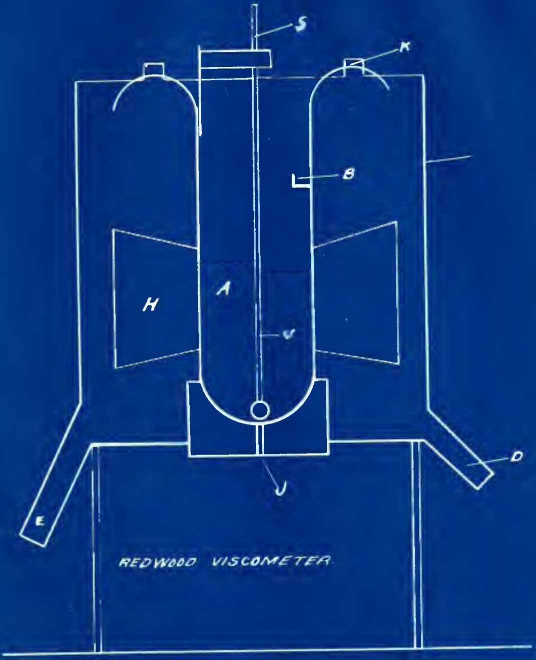
250°		300°	
Saybolt	Armour	Saybolt	Armour
39.0			
41.5		36.1	
42.5	36.8	36.5	33.0
40.0		33.029.2	29.2
35.0	28.6	33.1	30.8
35.1	32.0	35.8	32.8
40.2		34.9	33.2
42.2	36.0	35.0	
39.9		36.0	
40.6		40.0	35.0
45.1	39.2	38.8	36.4
46.2		36.4	34.4
41.4		41.1	34.0
42.0			
45.5	39.0	40.0	36.0
44.1	37.2	38.6	35.0
83.0	60.8	35.1	48.8
45.3	38.4	39.0	35.2
75.0	57.2	54.5	44.4
51.1	41.2	41.2	35.6

APPENDIX A

A series of intercomparisons between varioue viecosimetere have been made by the Committe D-2 of the American Society of Testing Materials. The curves are reproduced from pages 47 on. The curves were originally plotted against the Saybolt A and B viscosimeters. They are here, transferred to the Saybolt Universal. The instrument used were as follows:- Saybolt Univereal, Redwood, Engler, Tagliabue, Ostwald, Scott and the Pennsylvania Railroad Pipette.

Decscription of the Viscosimeters.

Redwood Viscosimeter.- This instrument consists of a cylinder A having a concave bottom which contains the jet J. A small brass ball valve sets on the jet when it is closed. The vessel A is contained in the center of the vessel C, which is furnished with a top D and a copper heating tube E. The stirring apparatus is made up of four light metal vanes which can be rotated around the tube A. The stirrer carries the thermometer.



REDWOOD VISCOMETER.

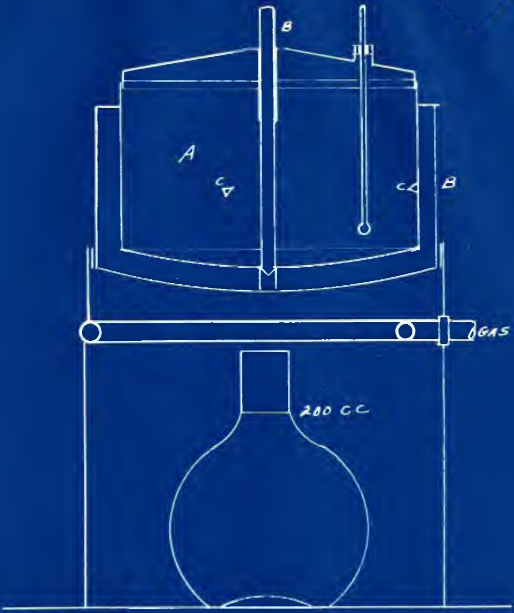
FIG 7.

COMPARISON OF VISCOSIMETERS

The outer vessel is fill with water or oil and heated by means of a gas burner placed under the projection E. The oil to be tested is place in A. The lid is placed on, leaving the thermometer immersed in the liguid. The valv V is raised, the oil flowing out into the flask below. The numbers of second required to fill a 50 c.c. flask is recorded as the viscosity of the oil on the Redwood Viscosimeter. The apparatus is shown in figure 7, page 43.

Engler Viscosimeter.- The Engler meter consists of an inner vessel A, figure 8, covered with a lid which carries a thermometer. A jet is located at the base. The plug valv B which closes the jet passes through the lid. The outer tank B is filled with water or oil and heated with a gas burner.

The oil under examination is placed in the vessel A until it reaches the three equal spaced studs C. The viscosity of the oil is the number of seconds it takes 200 c.c. to flow out of the jet.



ENGLER VISCOSIMETER

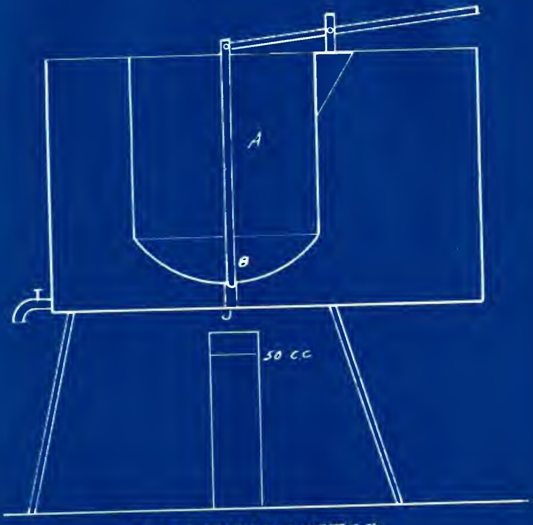
FIG 8

COMPARISON OF VISCOSIMETERS

Ostwald Viscosimeter.- This is a small glass pipette with a long capillary tube forming one side os a U-tube. The other side of which serves as the collection vessel for the sample after it has ran out.

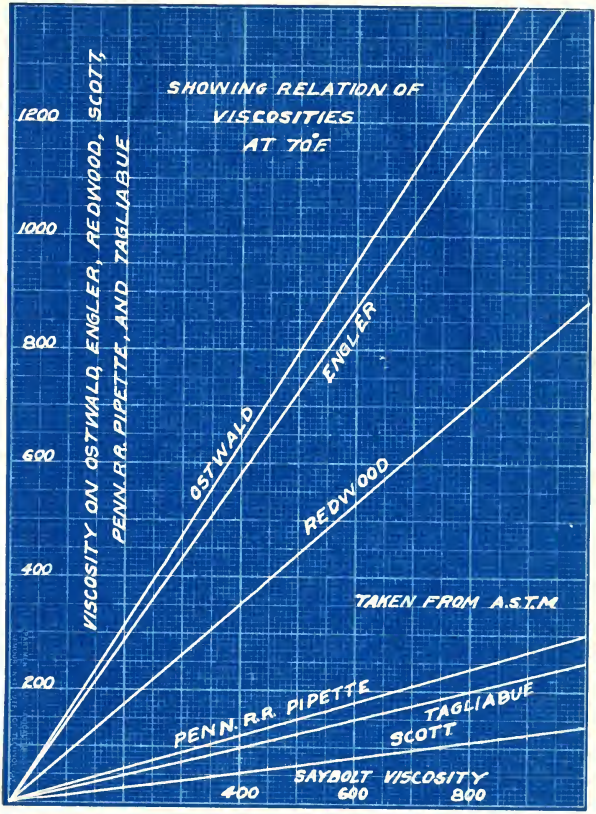
Scott Viscosimeter.- The Scott instrument consists of a container for the bath and the tube whose capacity is about 200 c.c. of liquid. The bath is heated by a burner. The tube is filled with the oil under consideration. When the oil has reached the desire temperature, the valve is opened. The viscosity is expressed in seconds of time it requires to fill a 50 c.c. flask. See figure 9.

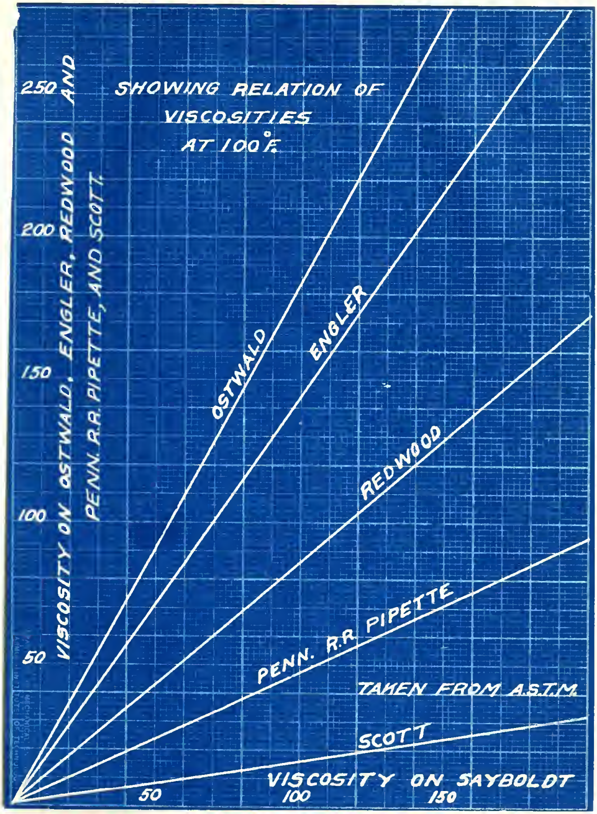
The Pennsylvania Railroad, or Dudle Pipette is a 100 c.c. pipette mounted in a box which has been provided with a glass cover. The air in the box can be heated. The viscosity is the numbers of seconds it takes 100 c.c. of oil to flow out of the pipette.

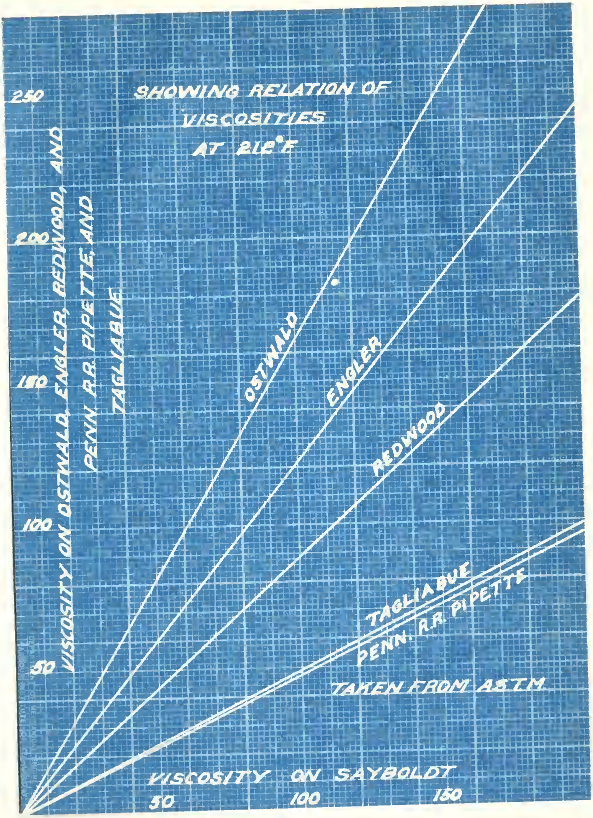


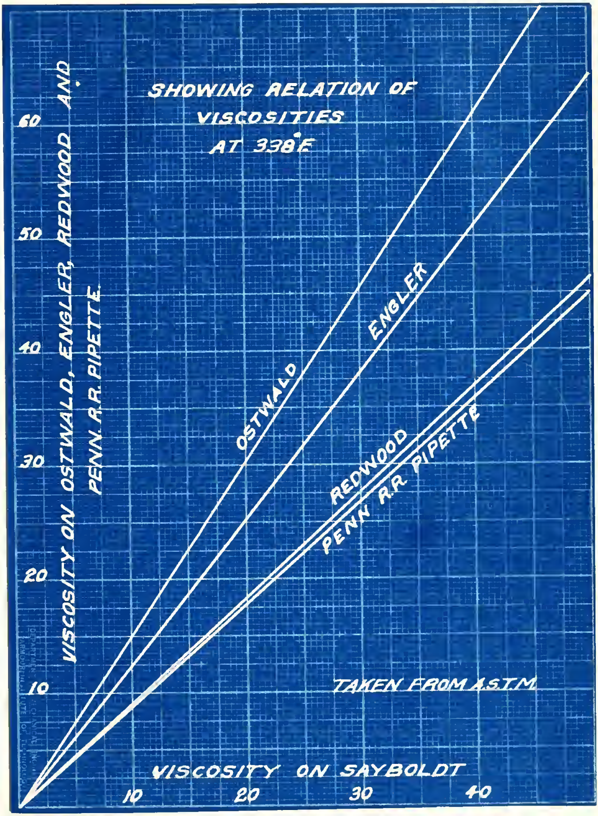
SCOTT VISCOSIMETER

FIG 9


SHOWING RELATION OF
VISCOSITIES
AT 70°F.
VISCOSITY ON OSTWALD, ENGLER, REDWOOD, SCOTT,
PENN. R.R. PIPETTE, AND TAGLIABUE
1200
1000
800
600
400
200
OSTWALD
ENGLER
REDWOOD
TAKEN FROM A.S.T.M
PENN. R.R. PIPETTE
TAGLIABUE
SCOTT
SAYBOLT VISCOSITY
400
600
800


SHOWING RELATION OF
VISCOSITIES
AT 100°F.
VISCOSITY ON OSTWALD, ENGLER, REDWOOD AND
PENN. R.R. PIPETTE, AND SCOTT.
250
200
150
100
50
OSTWALD
ENGLER
REDWOOD
PENN. R.R. PIPETTE
TAKEN FROM A.S.T.M.
SCOTT
VISCOSITY ON SAYBOLDT
50
100
150


SHOWING RELATION OF
VISCOSITIES
AT 212°F
VISCOSITY ON OSTWALD, ENGLER, REDWOOD, AND
PENN. R.R. PIPETTE AND
TAGLIABUE
250
200
150
100
50
OSTWALD
ENGLER
REDWOOD
TAGLIABUE
PENN. R.R. PIPETTE
TAKEN FROM A.S.T.M.
VISCOSITY ON SAYBOLDT
50
100
150


SHOWING RELATION OF
VISCOSITIES
AT 338°F
VISCOSITY ON OSTWALD, ENGLER, REDWOOD AND
PENN. R.R. PIPETTE
VISCOSITY ON SAYBOLDT
OSTWALD
ENGLER
REDWOOD
PENN R.R. PIPETTE
TAKEN FROM A.S.T.M.
10
20
30
40
50
60
10
20
30
40

BIBLIOGRAPHY.

Archbutt and Deeley; Lubrication and Lubricants, chap. 2,4 and 6.

Report of Committee, D-2; Intercomparison of Viscosimeters. American Society of Testing Materials, 10, page 117. (1910)

Tests of Lubricants; American Society of Testing Materials, 15, page 284. (1915)

Hayes and Lewis; Measurement of Viscosity, Am. Soc. Mech. Eng. Jl. Aug.,1916.

McIlhinney; Unit of Viscosity Measure. Jl. Ind. and Eng. Chem., May 1916.

Carpenter and Diedericks, Experimental Engineering, Chap. 9, page 248. (1913)

Catalogue, Veedol. Stratford; Lubrication of Internal Motors, Sec. Edition, 1916.